English Equivalents

$(9/5^{o}C) + 32$	= ^{o}F
1 centimeter	= 0.39 inch
1 meter	= 3.28 feet
1 hectare	= 2.47 acres
1 kilometer	= 0.62 mile
1 square meter	= 10.76 square feet
1 kilogram	= 2.20 pounds
1 gram	= 0.035 ounce

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PRELIMINARY RESULTS OF EXPERIMENTAL FIRES IN THE BLACK SPRUCE TYPE OF INTERIOR ALASKA

by

L. A. Viereck, *Principal Plant Ecologist*[1]

Joan Foote, *General Biologist*[1]

C. T. Dyrness, *Program Leader*

Keith Van Cleve, *Professor of Forestry (Soils)*[2]

Douglas Kane, *Professor of Water Resources and Civil Engineering*

and

Richard Seifert, *Research Associate*[3]

Abstract

Four units totaling 1 hectare in area were burned during the summer of 1976 in the Washington Creek experimental fire site near Fairbanks, Alaska. Original vegetation on the site consisted of an unevenly spaced stand of black spruce approximately 70 years old, with an understory of ericaceous shrubs and a nearly continuous cover of moss and lichen. One plot was burned on July 22 and the remainder on August 26 during two periods in the summer when the limits of the burning conditions were met. Measurements taken during the fire showed a difference of fire intensity among the four plots, which was also reflected in the percentage of area in each of five forest floor fire severity classes. Effects of the fires on vegetation, thickness of the organic layer, soil temperatures, phosphorus content of the forest floor, and the amounts of fuel are discussed. Seed fall from black spruce and revegetation of permanent plots during the 1976 season are given. Although the units were small, the burning under different weather conditions and with extra fuels placed on two of the plots resulted in a wide variation in the severity of burns and simulated conditions of a moderately severe wildfire.

KEYWORDS: Fire effects, fire use, black spruce, *Picea mariana*, Alaska (interior), taiga.

[1] Institute of Northern Forestry, Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, Fairbanks, Alaska.

[2] University of Alaska, Fairbanks.

[3] Institute of Water Resources, University of Alaska, Fairbanks.

INTRODUCTION

Land managers need to understand the effects of fires of varying intensities on the major taiga ecosystems. Recognizing that black spruce (*Picea mariana* (Mill.) B.S.P.) is the most widespread forest type in interior Alaska and also the type with the highest frequency of fire, the Institute of Northern Forestry (INF), the University of Alaska, and the U.S. Department of the Interior, Bureau of Land Managment (BLM) have worked together toward the establishment of the Washington Creek Fire Study and Training Area where basic research on the black spruce type, as well as experiments on prescribed burning in the black spruce type, can be conducted.

In 1976, through cooperation of INF, BLM, and the University of Alaska, the successful burning of four units within the Washington Creek experimental fire site marked the first carefully measured experimental fire in interior Alaska. It is the first of a planned series of studies on experimental burning in interior Alaska.

The fires were planned with two overall objectives:

1. To measure fire behavior under controlled burning conditions in the black spruce type in interior Alaska.
2. To determine the effects of fires of different intensities on the vegetation, surface organic layer, and soil.

A study plan was developed by INF scientists and a burning plan by BLM fire management personnel. The study plan called for collection of data before, during, and after the fire for information on prefire vegetation, fuels, and weather, fire behavior and intensity, and postfire changes in vegetation, fuels, soil nutrients, soil organic layers, and tree seed dispersal.

The experimental fire site occupies an area of about 1 ha (English equivalents are listed on page 28) on a ridgetop, between the drainages of Cushman Creek and Washington Creek at an elevation of 520 m. The area slopes to the southeast into the Washington Creek drainage. The soil at the site is shallow Fairplay silt loam with a shattered bedrock and stones at a depth of 20 to 50 cm. No permafrost was encountered; if it is present, it is well within the bedrock zone. The Washington Creek experimental fire site is located about 40 km north of Fairbanks.

The area was divided into five units (fig. 1). After the firelines were constructed, the undisturbed units ranged in size from 0.09 to 0.15 ha. Four of the units were burned and the fifth was left unburned for a control. An aerial view of the location and layout of the units and surrounding firelines is shown in figure 2.

METHODS

Unit Layout

The units were roughly diamond shaped (fig. 1). Two parallel transects, 8 m apart, were established along the long axis of each unit.

At 8-m intervals along each transect, five vegetation plots were established and permanently marked. Each of these 10 plots consisted of a 1-m^2 quadrat for sampling ground vegetation and low shrubs and a 4-m^2 circular area for sampling tall shrubs. Trees were sampled in a 4-m-wide belt centered on each of the transects (256 m^2 for each unit).

The percentage of cover in each species, stem counts by diameter class, and number of seedlings were recorded. Trees were counted and tallied by diameter class.

To facilitate observations of the rate of spread and to aid in relocating plots after the fire, we staked each unit into a grid. The location of the stakes is shown in figure 1.

Fuel Loading and Measurements

Because of the small size of the units we thought that they might not burn with the intensity of a severe wildfire. Therefore, to possibly increase the intensity of the fires, we loaded two of the units (1L and 4L) with additional fuels--black spruce cut from the firelines laid in rows within the units. We recorded the diameter of each tree at the time it was placed in the unit so we could determine biomass.

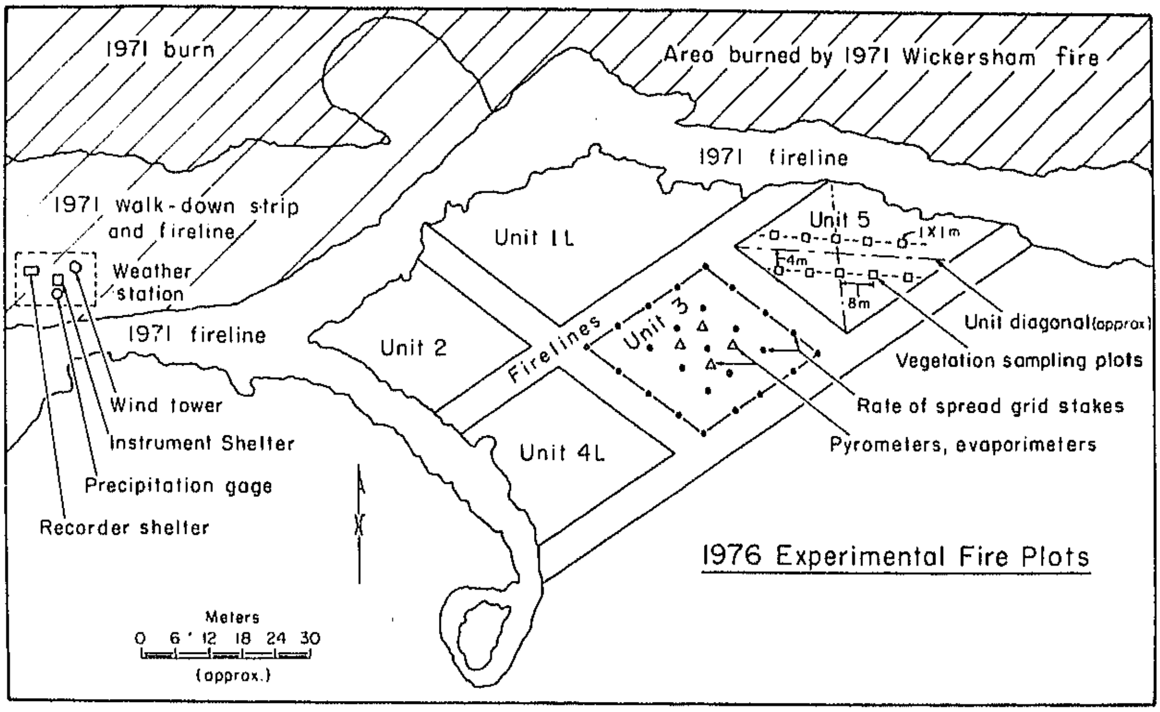

Figure 1.--Layout of the five units and the location of the weather station and firelines, Washington Creek experimental fire site. Unit 2 was burned on July 22, 1976; the other units on August 26, 1976. Unit 5 is the unburned control.

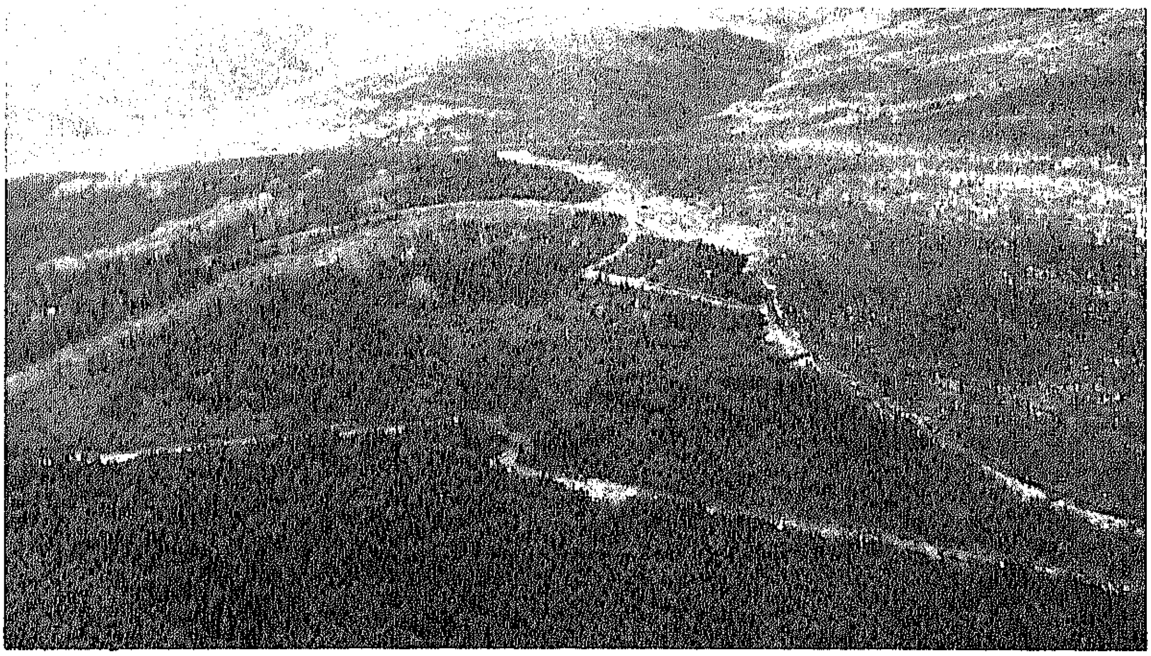

Figure 2.--Aerial view of 1976 experimental fire site. Old fire pattern of 70-year-old burn in the black spruce can be seen in the foreground. Area behind the site is the area burned by the 1971 Wickersham fire. Firelines along the ridge and in the foreground are from the 1971 fire. The walk-down strip diagonal to the left was put in in 1975 as part of suppression activities for the Alps fire in upper Washington Creek.

Fuel measurements were taken on permanently marked 10-m transects by the method developed by Brown (1971) and Brown and Roussopoulos (1974). This technique involves intersections of woody pieces with vertical sampling planes. Twenty randomly located, 10-m-long transects were sampled in each unit before the fire, and 10 were resampled after the fire. The loaded units were measured before and after the fuel was added.

Measurements of Fire Temperature

One of the more difficult aspects of this project was to categorize the intensity of each fire and describe its behavior and to assign some relative intensity to each. To obtain some idea of the actual heat intensity, we used several measuring devices.

1. Four pyrometer tiers were systematically located within each unit to be burned. Each tier consisted of three 7.5- by 12.5-cm pyrometers, one in the upper part of the organic layer, one from the air-organic material interface to 12 cm above the surface, and one 30 cm above the litter surface.
   The pyrometers were adapted from the design of Fenner and Bentley (1960) and used chemicals fusible at 66°, 121°, 288°, 454°, and 660°C, painted in strips. The lowest temperature is about the lethal temperature for plant tissues; the upper is about flame temperature.
2. Energy release was measured indirectly through water loss in four simple evaporimeters. The devices consisted of No. 10 cans with 250 ml of water. The evaporimeters were located adjacent to the pyrometers; they were set out just before the fire and were retrieved and measured soon afterward.
3. Near the center of each unit a single pyrometer was installed with heat sensitive paint on aluminum strips at 50-cm vertical intervals to a height of 2.75 m.
4. Heat sensitive pellets with a range from 43° to 83°C were placed on the moss surface and at 5- and 10-cm depth in the organic layer.

Percent Moisture in the Organic Layer

In each unit moisture in the organic layer was determined immediately before the fire at one to four locations, depending on time available. The samples were taken every 2 cm to a depth of 10 cm and the remaining organic sample was used as the last sample.

Thickness of the Organic Layer

To assess effects of fire, we measured the thickness of the forest floor both before and after burning. Measurements were taken at 1/2-m intervals along the two vegetation transects on each unit. Along each transect 63 observations of forest floor thickness were made, for a total of 126 per unit. Measurements were made with a steel probe with graduated 1-cm intervals.

In addition, degree of burning of the ground vegetation was estimated by five forest floor fire severity classes. These were:

1. Heavily burned: deep ash layer present, organic material in the soil consumed or nearly so to mineral soil, no discernible plant parts remaining.
2. Moderately burned: organic layer partially consumed, shallow ash layer present, parts of woody twigs remaining.
3. Lightly burned: plants charred but original form of mosses and twigs visible.
4. Scorched: moss and other plants brown or yellow but species usually identifiable.
5. Unburned: plant parts green and unchanged.

This information was recorded for each of the 10 vegetation plots and along the 10 randomly located 10-m-long fuel transects within each unit.

Soil Nutrients

Immediately after the fire, five samples of the forest floor were attained in a systematic fashion from each unit, including the unburned control. Samples were taken at the

approximate center of each unit and halfway between the center and each corner. A 15-cm-diameter core of the forest floor was obtained from a zone judged to represent the average degree of combustion of the forest floor in each location. Samples were immediately transferred to plastic bags, care was taken to avoid contamination of lower portions of cores by ash from the burned surface. The cores were separated into genetic horizons in the laboratory. Layer thickness, fresh weight, and ovendry (65°C) moisture content were estimated for subsequent bulk density calculations. Separated layers were frozen until analyzed. The acid fluoride soluble phosphorus was determined for each sample.

CONDITIONS PRIOR TO AND DURING BURNING

Vegetation

Vegetation of the area consisted of an unevenly spaced stand of black spruce approximately 70 years old, with an understory of shrubs, herbs mosses, and lichens. Vegetation data are given in tables 1 and 2.

Numbers of trees over 2.5-cm d.b.h. in the four units varied from 2,226 to 5,468 per hectare. Average diameters ranged from 4.3 to 4.9 cm, but the largest trees in the plots had diameters in the 9- to 10-cm class and heights of 6.5 m. Trees as large as 15-cm d.b.h. and 10 m in height were cleared from the fireline. A few paper birch *(Betula papyrifera)*, alder (*Alnus crispa*), and willow (*Salix* spp.) were scattered in the units. The trees were unevenly distributed so that there were small open areas between the tree clumps. In these small clearings the low shrubs--lingenberry (*Vaccinium vitis-idaea*), blueberry (*V. uliginosum*), and Labrador tea (*Ledum groenlandicum*)--were common; and these were the main areas for the lichen mats. Mosses were abundant throughout the stand; cover values ranged from 72 to 85 percent in the different units.

Fuel Load

Using regression equations developed by Van Cleve and Hunt[4] for black spruce at a nearby study site at Washington Creek, we determined the biomass of the fuels loaded on units 1L and 4L (table 3). Unit 1L was more heavily loaded than unit 4L, the total being 26 500 kg/ha for 1L and 15 600 kg/ha for 4L.

The units were loaded in June 1975; burning was planned for that summer. Therefore, although most of the needles had fallen from the trees by the summer of 1976, the fine fuels had an additional summer to cure.

Limits of the Burning Conditions and the Weather Preceding the Fires

The limits of the burning conditions were written by Roy Percival, Bureau of Land Management, with the anticipation that the fire would duplicate a moderately intense wildfire, in spite of the small size of the units. The foremost consideration in formulating the prescription was to obtain burning within safe control limits. The conditions necessary for the fire were the following:

1. Fuel moisture sticks (range)	5 to 20 percent
2. Humidity (range)	20 to 45 percent
3. Speed and direction of wind	0-4.5 m/s (0 to 10 mi/h) from S.W. to S.E.
4. Type of fire	Head, strip
5. Time of day	1400 to 1800 hours
6. Buildup index[5]	10 or above
7. Temperature	10° to 27°C (50° to 80°F)

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[4] Progress report and proposed research for the continuation proposal dealing with "The structure and function of a black spruce (*Picea mariana* (Mill.) B.S.P) forest in relation to other fire affected taiga ecosystems"; K. Van Cleve and C. T. Dyrness co-principal investigators. March 1977. On file at Department of Forest Soils, University of Alaska, Fairbanks. 205 p.

[5] A number expressing the cumulative effects of daily drying factors and precipitation in fuels with a 10-day timelag constant.

Table 1--Percent cover of vegetation and number of stems per hectare of tall shrubs and tree seedlings before burning, Washington Creek 1976 experimental fire site[1]

Vegetation	Unit 1L	Unit 2	Unit 3	Unit 4L
	PERCENT COVER (NUMBER OF STEMS PER HECTARE)			
Tree seedlings:				
Picea mariana (Mill.) B.S.P.	2±0.6 (4,250±1,760)	2±2.5 (4,500±1,760)	2±0.6 (5,750±2,658)	1±0.4 (3,000±1,090)
Betula papyrifera Marsh.				1±.2 (1,250±990)
Populus tremuloides Michx.				1±.1 (250±250)
Tall shrubs:				
Alnus crispa (Ait.) Pursh	2±1.2 (1,750±1,730)	4±.3 (3,500±2,335)	8±4.8 (7,500±4,166)	
Salix scouleriana Barratt	5±2.5 (3,750±1,730)	4±2.3 (3,000±1,796)	2±1.5 (3,000±1,976)	10±5.2 (15,000±8,090)
Salix alaxensis (Anderss.) Cov.	1±.5 (1,500±1,480)			
	PERCENT COVER			
Low shrubs:				
Empetrum nigrum L.	3±1.1	5±1.3		5±1.5
Ledum groenlandicum Oeder	3±1.5	3±.3	4±.3	4±1.9
Vaccinium uliginosum L.	18±3.7	25±3.9	18±6.8	18±3.9
Vaccinium vitis-idaea L.	8±1.9	11±2.2	6±.9	12±1.9
Herbs:				
Calamagrostis canadensis (Michx.) Beauv.	1±.2	1±.2	1±.2	
Cornus canadensis L.	1±.4		1±.3	
Geocaulon lividum (Richards.) Fern.	1±.3	1±.4	5±1.2	4±1.1
Lycopodium complanatum L.	1±.3	1±.3		.1±.1
Mosses:				
Aulacomnium palustre (Hedw.) Schwaeger.				1±.1
Dicranum undulatum Brid.		1±.9	1±.3	2±1.0
Hylocomium splendens (Hedw.) B.S.G.	20±5.0	18±5.3	31±7.7	23±5.8
Ptilium crista-castrensis (Hedw.) DeNot	3±2.0			2±1.1
Pleurozium schreberi (Brid.) Mitt.	61±9.6	62±6.4	43±6.4	45±7.9
Polytrichum commune Hedw.	1±.6	.5±.3	1±.5	3±1.4

Table 1--Continued

Vegetation	Unit			
	1L	2	3	4L
	PERCENT COVER			
Lichens:				
Cetraria cucullata (Bell.) Ach.				1±.2
Cladonia gracilis (L.) Willd.				1±.5
Cladonia rangiferina (L.) Web.	1±1.7	5±2.9		4±2.0
Cladonia sylvatica (L.) Hoffm.			1±.2	4±3.0
Cladonia spp.		.7±.5	1±.2	1±.5
Nephroma arcticum (L.) Torss.	5±10.9	4±1.5	1±.1	3±1.7
Peltigera aphthosa (L.) Willd.	1±3.1	2±1.1	1±.2	7±3.8
Peltigera canina (L.) Willd.			1±.3	1±.5
Stereocaulon paschale (L.) Hoffm.				1±.1
Total cover:				
Trees	19±5.6	12±4.0	28±6.6	8±3.0
Tall shrubs	9±2.6	7±1.8	3±4.5	14±5.3
Low shrubs	32±4.9	44±5.7	28±7.5	38±5.4
Herbs	3±.4	2±.5	6±1.3	4±1.1
Mosses	85±6.1	82±6.0	78±8.2	72±7.3
Lichens	9±3.9	12±4.8	3±.5	22±7.0
Deadwood	12±2.1	10±2.6	16±1.2	14±2.1
Litter	22±3.7	20±4.4	30±6.5	22±4.3

1/ Measurements were taken in 1975. ± = standard error.

Table 2--Density, height, diameter, and biomass of trees before burning, Washington Creek 1976 experimental fire site[1/]

Item	Unit			
	1L	2	3	4L
Density (stems per hectare):[2/]				
Black spruce trees	3,398±497	5,468±1,878	4,179±2,707	2,226±939
Paper birch trees	0	741±497	78±110	117±55
Black spruce saplings[3/]	1,490±432	1,953±1,761	8,758±1,933	1,874±111
Paper birch saplings[3/]	0	78±110	0	0
Dead trees	156±0	703±110	468±110	156±110
Average height of black spruce (meters)	3.4	3.4	3.5	3.1
Average diameter of black spruce (centimeters; range 2.5-10)	4.82	4.80	4.97	4.34
Estimated biomass of live black spruce (kilograms per hectare):[4/]				
Total tree	19 020	23 780	18 250	6 560
Needles	4 040	4 030	3 844	1 530
Bark	2 530	3 160	2 420	900
Cones	620	780	600	210
Live branches	2 350	2 940	2 250	850
Dead branches	850	1 060	810	310
Bole	6 650	8 310	7 980	2 740

1/ ± = standard error.

2/ Based on 2 transects, 4 meters wide and 32 meters long, in each unit.

3/ Under 2.5-centimeter d.b.h.

4/ Weights determined by regression equations developed by Van Cleve and Hunt (data on file at Department of Forest Soils, University of Alaska, Fairbanks; used with permission); where, log y = log a + b log x; y = weight; x = basal diameter; and a and b are constants determined for each component and for the total tree. Total tree weight does not equal the sum of the components.

Conditions for the experimental fire were met in early July of 1975, but a very intense wildfire that burned 2 000 hectares within the Washington Creek drainage caused the experimental fire to be cancelled. Rainy weather during the remainder of the summer prevented the burning conditions from being met again in 1975.

At Fairbanks, 30 km southeast of the site, the 1976 summer season was early and somewhat warmer than average. Figure 3 shows the 30-year average for degree days for Fairbanks, the 1976 curve for Fairbanks, and the degree day accumulation for a black spruce stand at Wickersham, less than 2 km away and in a similar topographic position. Table 4 lists the daily temperatures at the site and figure 4 shows them graphically.

At the site of the experimental fire, temperatures and precipitation were recorded continuously starting June 2, when a Forest Service rain gage, a tipping-bucket recording gage, and fuel moisture sticks were installed. Figure 4 also shows the precipitation record, relative humidity, and temperature for the Washington Creek site for June, July, and August.

As is normal for the general Fairbanks region, precipitation

Table 3--Estimates of biomass of black spruce added to units 1L and 4L, Washington Creek experimental fire site, June 1975

Component[1/]	Unit 1L	Unit 4L
	Kilograms per hectare[2/]	
Total tree	26 500	15 600
Needles	4 500	2 000
Bark	3 400	2 000
Cones	900	500
Live branches	3 100	1 800
Dead branches	1 100	700
Bole	12 000	7 200

1/ Each component, including total, was calculated separately from regression equations developed by Van Cleve and Hunt (data on file at Department of Forest Soils, University of Alaska, Fairbanks; used with permission); where, log y = log a + b log x; y = weight; x = basal diameter; and a and b are constants determined for each component and for the total tree. Total does not equal sum of components.

2/ Based on total weight added to the unit, converted to kilograms per hectare, and rounded to closest 100 kg.

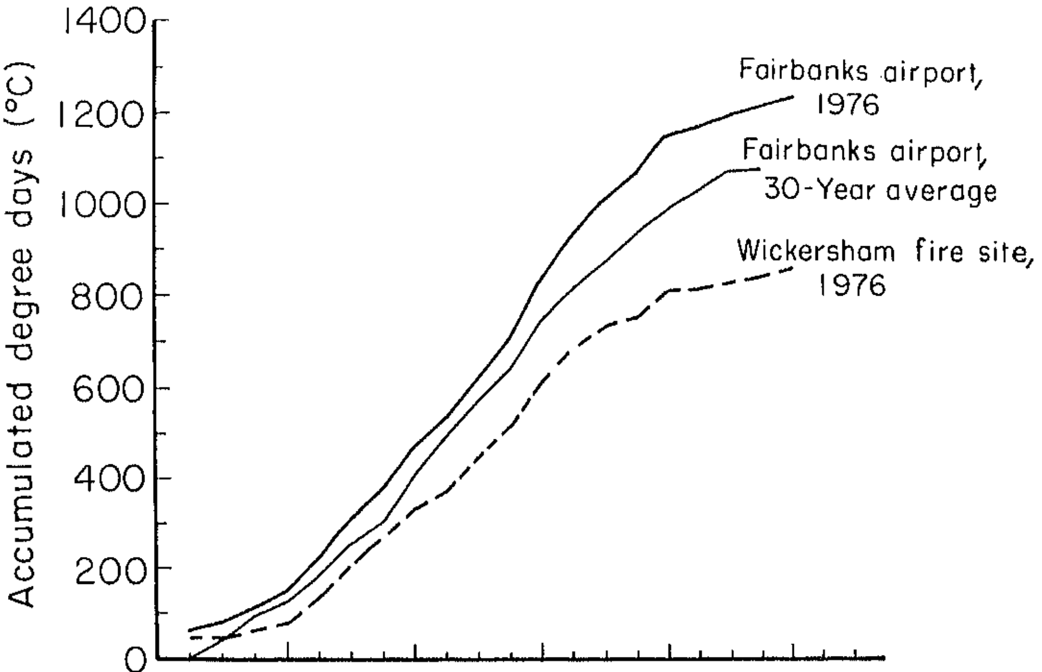


Figure 3.--Accumulated degree days (based on 5°C) for 30-year average and for 1976 at Fairbanks airport and for 1976 at the Wickersham site, 2 km from the Washington Creek experimental fire site.

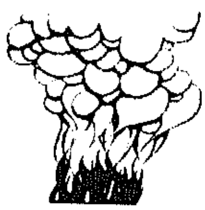
Table 4--Average, maximum, and minimum air temperatures (°C), Washington Creek experimental fire site, 1976[1]

Day of month	June			July			August			September		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
1	[2]14	[3]	[3]	12	15	10	21	28	14	9	16	7
2	[2]15	[3]	[3]	[2]13	[3]	[3]	20	26	16	10	17	6
3	14	19	10	[2]13	[3]	[3]	19	24	14	9	15	5
4	14	20	9	[2]13	[3]	[3]	19	24	15	2	6	-1
5	15	22	10	[2]11	[3]	[3]	20	25	14	4	10	-3
6	7	12	4	19	22	14	20	28	16	6	12	5
7	9	14	4	19	25	13	16	19	13	9	15	4
8	10	15	4	15	21	11	[2]15	[3]	[3]			
9	12	17	8	15	20	10	18	21	14			
10	15	20	8	17	22	10	18	24	13			
11	14	19	9	18	23	13	19	24	14			
12	15	21	9	17	22	12	17	22	13			
13	18	24	11	17	23	12	17	24	11			
14	20	26	13	16	21	10	19	25	13			
15	18	24	13	15	20	11	15	18	11			
16	17	24	10	16	22	12	13	18	9			
17	12	18	8	14	20	10	11	16	7			
18	9	14	7	15	21	11	12	18	10			
19	12	17	9	17	22	10	11	16	7			
20	14	20	7	20	26	14	11	17	5			
21	13	19	9	22	29	15	12	17	5			
22	12	16	6	20	29	14	13	19	8			
23	9	11	7	19	27	14	15	21	9			
24	10	14	8	17	21	12	17	24	12			
25	11	14	8	16	20	13	17	22	12			
26	15	22	8	14	17	12	16	23	11			
27	18	23	14	15	21	11	15	21	10			
28	14	17	9	17	21	12	13	18	10			
29	12	18	9	20	27	13	13	18	8			
30	13	17	9	13	17	10	12	17	7			
31				16	22	7	9	17	5			

[1] Average temperature is based on 12 readings at 2-hour intervals. A thermograph was installed June 2 and removed September 8.

[2] Data reconstructed from Wickersham site.

[3] Missing data.



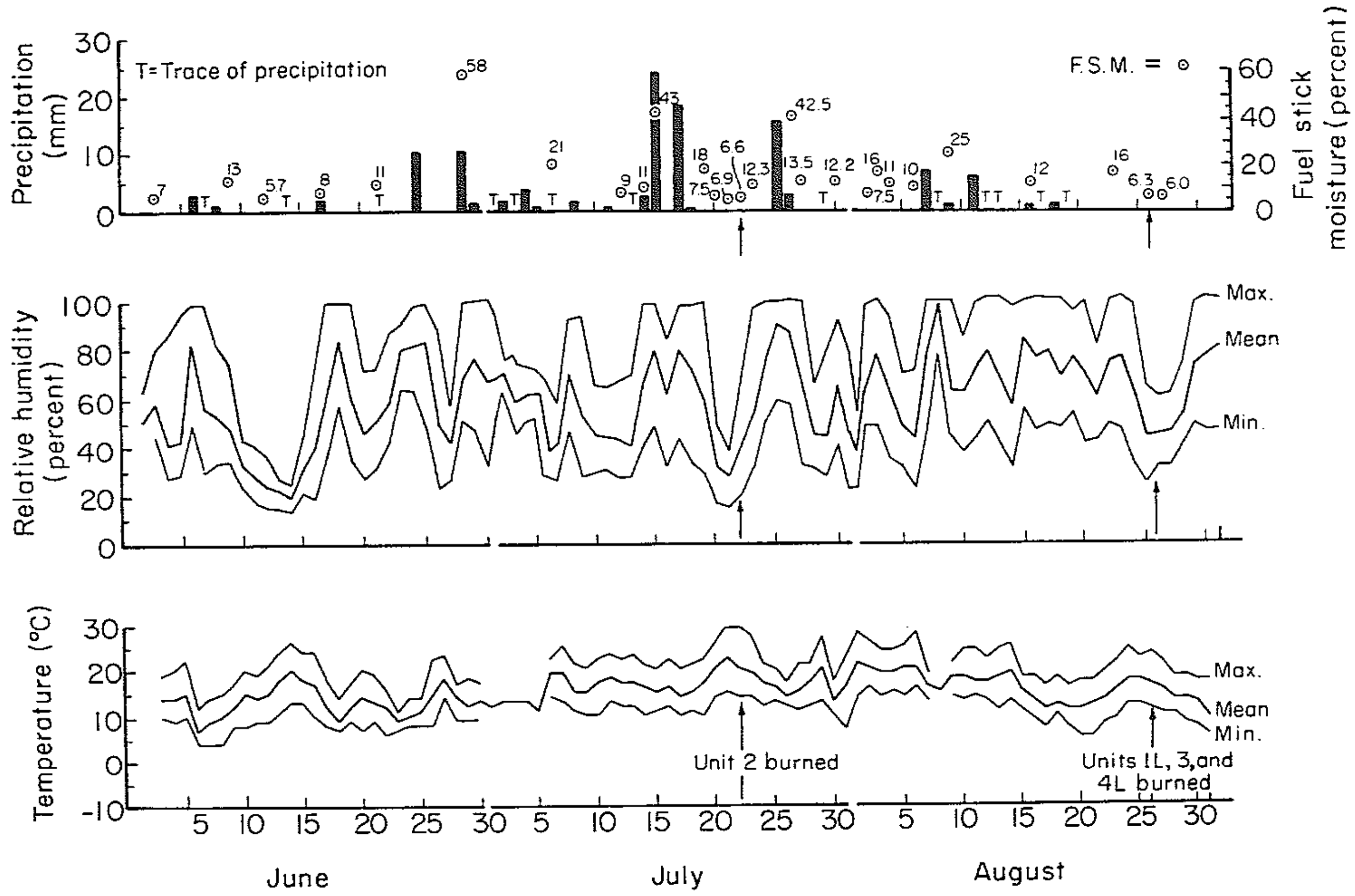


Figure 4.--Air temperature, precipitation, relative humidity, and moisture in fuel sticks (F.S.M.) for the Washington Creek experimental fire site, summer 1976.

during April was low. Usually at Fairbanks precipitation increases through the summer; monthly averages in millimeters are: April 6.4, May 18.6, June 35.3, July 46.7, and August 55.9. No long-term records are available for Washington Creek, but the pattern can be assumed to be much the same, with somewhat higher amounts because of the higher elevation.

At Washington Creek 36 mm of precipitation fell in May, but only 27 in June. The burning condition limits were first met between June 10 and 15, but at that time a large number of wildfires kept the BLM fire crews busy and prevented any burning attempt. Cooler weather with high relative humidity and some precipitation prevented the prescribed conditions from being met again in June.

The month of July had an interesting precipitation pattern. Until July 15, only 17 mm of rain fell. Then, on July 15, a cloudburst dropped 24 mm on the site in less than 1 hour and a thunderstorm on the 17th added another 19 mm. After this 43 mm of rain in 3 days, prospects for the experimental fire conditions being met in July did not appear likely; however, a hot rainless period from July 16 to July 22 lowered the relative humidity to 32 percent and the moisture in the fuel sticks to 6.6 percent so that one unit (2) could be burned on July 22 within the limits set.

When unit 2 was burned on July 22, the organic layer was high in water content from the previous heavy rains. Burning of the other units on July 22 was cancelled because of a rain and hail storm, accompanied by strong gusty winds.

During the 1st week in August, it appeared that burning conditions would again be met. In the afternoon of August 6, the relative humidity was 34 percent and the fuel stick moisture had dropped to 7.8 percent. The second series of fi--s was planned for August 7, but air moved into the area, and rning was cancelled. On 8, 10 mm of rain fell and it unlikely that conditions be met again in 1976. The der of August was exceptionally warm and dry; only 8 mm of precipitation fell between August 9 and 18. The conditions were again met on August 26, and the other three units were burned.

In the 1976 fire season, periods that met the fire conditions occurred several times during the summer; but the intervals when the conditions were met were extremely brief. This is especially illustrated by the graph of relative humidity (fig. 4) which shows the periods in June, July, and August when the average humidity fell below 50 percent.

Conditions at the Time of Burning and Ignition Procedures

The first unit to be burned (2) was ignited at 1152 on July 22, 1976. Conditions at the time of ignition were:

Fuel stick moisture content	6.6 percent
Relative humidity	32 percent
Speed and direction of wind	0-2.2 m/s (0 to 5 mi/h), from S.S.E.
Temperature	24°C (76°F)

Before ignition, two tanker trucks were positioned and hoses laid out along the firebreaks. All persons at the site were briefed on the sequence of ignition and predicted fire behavior. Safety was stressed, and escape routes were set and discussed. Figure 5 shows the organic layer moisture content by volume (obtained by multiplying the moisture content (expressed as weight) by the bulk density, which in the upper 10 cm varied from 0.02 to 0.08 g/cm^3) just before the fire. The moisture content in the top 10-cm layers was only slightly higher on July 22 than on August 26, but below the 10-cm level it was much higher on July 22.

The unit was ignited on the lower southeast corner; heat developed rapidly, and the fire soon started to crown. It moved across the unit in 7 minutes. The fire was especially intense near the center of the unit.

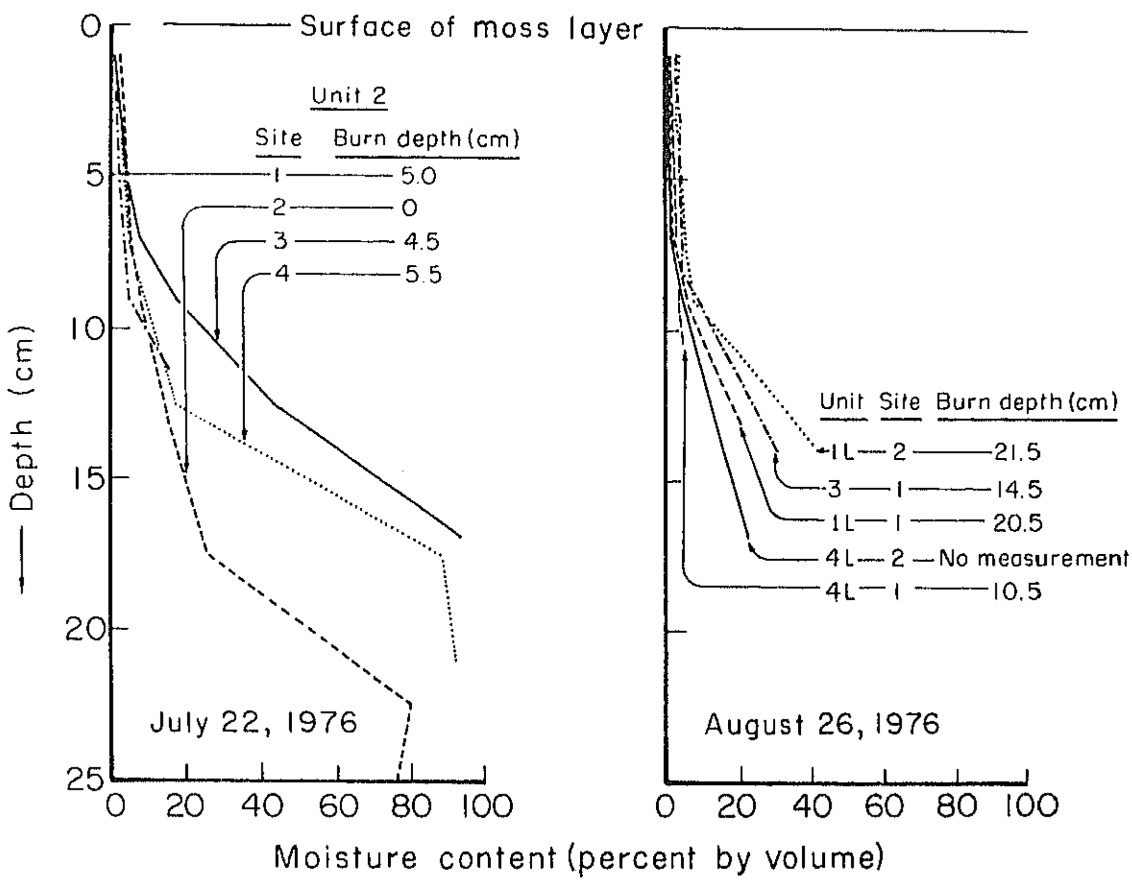


Figure 5.--Moisture content by volume as a function of depth for all units burned in the summer of 1976, Washington Creek experimental fire site.

This fire did not burn heavily in the organic layer, and it was possible to work in the plot within a few minutes of time of burning. As indicated by the vertical temperature profile (table 5) and the high percentage of tree needles consumed, the fire was hot at the 0- to 3-m level but not within the forest floor. At the 5-cm depth in the soil, the temperature sensitive pellet with the lowest melting point, 43°C, did not melt; at the 5-cm layer above the ground, the heat sensitive paint with the highest melting point melted at 121°C.

Soon after, preparations were started for burning unit 1L. But before these preparations were very far along, a thunderstorm, bringing heavy rains, moved into the area; this precluded any further fires at that time.

From August 1 to August 26, precipitation at the study site totaled only 16 mm. By August 26, burning conditions were again met; and the last three units were burned. Conditions at the time of ignition were:

Fuel stick moisture content	6.6 percent
Relative humidity	40 percent
Speed and direction of wind	2.7-3.6 m/s (6 to 8 mi/h), from S.S.E.
Temperature	19°C (66°F)

Table 5--Some measured indications of fire intensity in 4 units burned in 1976, Washington Creek experimental fire site

Indicator	Height, m	Unit 1L	Unit 2	Unit 3	Unit 4L
Time to cover entire unit (min)		9	7	29	6
Average H_2O evaporated (ml)		65	5	16	107
Range (ml)		[1] 0-70	0-10	0-30	20-210
Highest temperatures (°C) recorded from heat sensitive paints at each height on center pyrometer	2.75	66	288	66	454
	2.25	66	288	66	454
	1.75	66	288	121	454
	1.25	121	288	121	[2] 660
	.75	121	288	121	[2] 660
	.25	288	288	288	[2] 660
Highest temperature recorded from heat sensitive paints (°C):					
6 to 15 cm (above surface		288	288	288	454
Range		<43-288	121-288	<43-288	288-454
0 to 5 cm (above surface)		288	121	288	454
Range		<43-288	121-121	<43-288	121-454
2 to 3 cm in organic layer		No data	43	288	121
Highest temperature recorded by temperature sensitive pellets (°C):					
Surface		[3] >83	[3] >83	[3] >83	[3] >83
5-cm depth in organic layer		43	43	43	69
10-cm depth in organic layer		<43	<43	<43	<73

[1] 1 can tipped over--1 can in unburned area.
[2] Temperature sensitive paint with highest temperature tolerance (660°C) melted.
[3] Pellets with highest melting point (83°C) melted.
[4] Pellets with lowest melting point (43°C) did not melt.

Unit 1L was ignited at 1242 on August 26, 1976, beginning at the southeast corner (fig. 6). Within 1 minute, the fire moved into the tree crowns along the lower edge; however, the burning of crowns became spotty except near the center of the unit. At 1250, the crowns in one area burned with flames to 16 m. The entire area was covered by fire in about 9 minutes, and most of the active burning was over by 1256. Unlike the July 22 fire, the fire on all the units burned on August 26 continued to burn in the organic layer for several hours and in a few spots smoldered and periodically flamed for several days.

The 26 500 kg/ha of fuels that had been loaded on this unit did not seem to contribute significantly to the fire intensity but might have resulted in the large number of persisting ground fires. The limited data from the heat paints, temperature sensitive pellets, and water evaporation indicated that this was one of the least intense of the four fires.

Unit 4L was ignited at 1413. The pattern of ignition was

Figure 6.--Lighting the fire at unit 1L; photo shows rapidity with which tree crowns began to burn.

altered to reduce the fire spotting experienced during the fire on unit 1L. Ignition was started in the middle of the southeast boundary and continued

Figure 7.--Lighting the fire in unit 4L; photo shows rapid development of intense crown fire.

to the southwest boundary to the corner of the unit (fig. 7). Because of light winds during burning, most of the spot fires occurred just uphill in previously burned unit 2. The fire completed its run across the unit in 6 minutes.

From all indications, the fire in unit 4L was the hottest. There were several areas where observers indicated a "very hot crown fire." The loaded fuel, 15 600 kg/ha, seemed to add to the spread and intensity of the fire and to the depth to which it burned into the organic layer.

Temperatures were hotter at all levels than in the other units. The aluminum backing for the heat paints burned at the three lower levels on the vertical pyrometer, and temperatures at 2.75 m were 454°C or greater. Temperatures at 10 cm in the soil reached 73°C (table 5). Nearly 90 percent of the trees had at least 50 percent of the needles consumed, and nearly 70 percent of the ground vegetation was heavily or moderately burned.

Unit 3 was ignited at 1501. It was touched off at the east corner, and from there the torchmen moved northeast and southeast along the perimeter (fig. 1).

There was some spotty torching; but the fire was primarily a slow-moving ground fire, very different from the fires in the other three units. The fire took 29 minutes to burn to the other end of the unit.

The temperature profile and the low percentage of needles consumed indicated that this fire was the least hot of the fires; however, the ground fire continued actively for several days and resulted in nearly 50 percent of the ground vegetation being heavily or moderately burned.

EFFECTS OF THE FIRES

Thickness of the Forest Floor

One of the most important parameters on which to measure

effects of fire is forest floor thickness. In this region, where moss and lichen remains can quickly accumulate to depths of well over 50 cm, causing lower soil temperatures and immobilizing much of the nutrient capital, what fire does to this layer is of paramount importance.

Results of the forest floor measurements are summarized in table 6. From these results, one would infer that fires burned most intensely on units 3 and 4L and that burning was least severe on unit 2 and intermediate on 1L. Unit 2, with only 24-percent reduction in forest floor thickness, was burned a month earlier than the other three plots at a time when moisture content of the forest floor was considerably higher (fig. 5). Consequently, although the fire built up considerable heat and moved quickly through the crowns of the trees, it consumed only a few surface centimeters of the forest floor because of the high moisture content.

Because of low amounts of earlier rainfall, the moisture content of the forest floor was relatively low by late August, especially below 10 cm, when units 1L, 3, and 4L were burned (fig. 5). This set the stage for the effects measured on units 3 and 4L. Although these two units were almost identical in reduction of forest floor thickness (table 6), the characteristics of the fires were dissimilar. Unit 4L was subjected to an intense fire which entered the crowns soon after ignition and quickly moved across the unit. After the fire, the unit appeared heavily burned and almost 100 percent of the forest floor was deeply charred. In contrast, unit 3 experienced a slow, creeping ground fire which torched only in a few isolated trees and gave the appearance of a far less intense fire. Many green trees remained after the fire and an appreciable portion of the forest floor was unburned. The almost two-thirds reduction in forest floor thickness measured on unit 3 can be attributed to the fact that in areas covered by the ground fire virtually all the organic material was consumed down to mineral soil. Thus, measurements on unit 3 generally either showed little change (unburned or lightly charred) or virtually all organic material was consumed by a deeply burning ground fire. On the other hand, postfire measurements on unit 4L showed a more uniform decrease in forest floor thickness.

No significant effect of fuel loading could be detected on forest floor thickness after the fire (table 6). We can only speculate what the results would have been had the units been burned soon after fuel loading. But almost certainly fires on the loaded units would have been

Table 6--Mean forest floor thickness before and after experimental fire in 4 units at the Washington Creek experimental fire site[1/]

Item	Unit			
	1L	2	3	4L
	Centimeters			
Thickness before burning	21.6±.67	19.8±.57	23.2±.66	22.4±.67
Thickness after burning	11.6±.68	14.9±.72	7.8±.55	7.2±.49
Preburn-postburn difference	10.1	4.9	15.4	15.2
	Percent			
Reduction in thickness	43	24	61	62

[1/] Each value is based on 126 observations; ± = standard error.

considerably hotter had cured needles still been on the loaded slash.

These results indicate that controlled burning can effectively reduce forest floor thickness in black spruce. This burning causes nutrient mineralization, soil warming, and stepped up rates of organic matter decomposition. It also creates a favorable environment for regeneration of shrubs and trees by stimulating sprouting and exposing bare mineral seed bed. These results also show the importance of the moisture status of the forest floor in controlling some effects of fire. If the burning prescription is aimed at reducing forest floor thickness, its moisture content, as well as the moisture content of above-ground fuels, should be monitored.

It is well to keep in mind that considering only the average reduction in forest floor thickness can be somewhat misleading, for this viewpoint can give the impression that forest floor materials were burned uniformly over an entire area. Actually this is seldom the case. Most often, after a fire the forest floor constitutes a mosaic of widely different conditions--from completely unburned to severely burned. For this reason, the proportion of the area within burning condition classes was measured, as well as forest floor thickness (table 7).

The high degree of variability in the data indicates to some degree the variability with which the fire consumed the ground vegetation. Especially in the three units burned in August, there were many examples of total consumption of the organic layer; and yet only a few decimeters away the vegetation was scorched or unburned.

Some differences in the degree of burning of the ground vegetation are apparent. In unit 2, for example, which had a hot crown fire but was burned when the underlying organic layers were moist, 97 percent of the ground vegetation was in the lightly burned class. Only occasional spots, mostly at the base of trees, burned to mineral soil. Because of the heat from the crown fire, however, none of the plots or transects escaped scorching of the moss layer.

The greatest amount of destruction of the ground vegetation occurred in loaded unit 4L. In that unit,

Table 7--Area in 5 forest floor fire severity classes after fire in black spruce, Washington Creek experimental fire site[1]

Fire severity classes	Unit			
	1L	2	3	4L
	Percent, based on ten 1-m^2 plots			
1. Heavily burned	24.0±11.1	2.0±1.5	37.0±10.2	49.4±13.5
2. Moderately burned	25.0±11.2	.2± .2	11.9± 4.1	6.1± 6.4
3. Lightly burned	37.5±13.2	97.1±1.5	49.3± 9.3	34.5±12.4
4. Scorched	7.5± 5.1	.7± .5	1.8± 1.0	0
5. Unburned	6.0± 5.4	0	0	0
	Percent, based on ten 10-m-long transects			
1. Heavily burned	34.2± 5.9	2.1± 1.0	36.8± 5.1	58.0± 4.9
2. Moderately burned	21.0± 6.2	16.0± 9.6	16.0± 3.9	17.0± 2.9
3. Lightly burned	36.1± 8.4	75.0±10.2	42.0± 4.6	24.9± 5.7
4. Scorched	1.0± .6	6.9±2.1	4.5± 1.1	.1± .03
5. Unburned	7.7± 5.8	0	1.7± .5	0

1/ ± = standard error.

nearly 50 percent of the area was heavily burned and in most cases the fire burned to mineral soil. No scorched or unburned area was found, which showed that the whole unit was lightly to heavily burned.

The data for unit 3 show that the fire did not burn as a hot crown fire but was primarily a slow-burning ground fire, which consumed much of the ground vegetation and organic layer. Much of the area was within the lightly burned class, but approximately 40 percent of the unit was burned nearly to mineral soil.

Unit 1L showed the largest percentage of unburned area in spite of the fact that the fire burned rapidly through the stand. The high percentage of unburned area resulted primarily from one upper corner not burning.

In summary, the two burning dates with different forest floor moisture conditions, the loading of two of the units, and the difference in the intensity of the crown fires in the units resulted in a wide variation in the degree of burning of the ground vegetation both within each unit and between units. This variation will provide a good opportunity to follow the revegetation under these varying conditions of fire intensity.

Soil Temperatures

Temperatures were taken with a 90-cm metal temperature probe in unit 2 and control unit 5. Because of the shallow stony soils, it was usually impossible to insert the probe deeper than 20 cm.

The few soil temperature readings from the summer of 1976 are shown in table 8. On July 22, soil temperatures were taken at unit 2 at 1100, less than an hour before ignition. They were taken again at 1218, less than 20 minutes after the fire. There was an increase of 7°C at the 5-cm level, 6°C at 10 cm, 3°C at 15 cm, but no increase below that level. After 24 hours the temperatures in the burned unit were nearly the same as those in control unit 5.

Table 8--Soil temperature (°C) for units 2 and 5, Washington Creek experimental fire site[1]

Unit and depth in soil	Before burning		After burning		
	June 15	July 22	July 22	July 23	July 27
Unit 2 (burned July 22):					
-5 cm	5.3±0.7	14.3±2.2	21.3±1.3	17.3±1.4	12.7± .6
-10 cm	4.0± .6	10.7±1.9	16.7±2.4	12.0±1.2	10.3± .9
-15 cm	2.0±0	10.2± .3	13.3±3.3	7.7± .3	9.0± .6
-20 cm	1.5±0	5.3± .3	5.7± .3	6.0± .6	6.7± .7
Unit 5 (unburned control):					
-5 cm	8.7± .9			17.3± .7	13.3± .3
-10 cm	7.0± .6			10.7±1.2	10.0±1.2
-15 cm	5.3± .7			6.7± .3	8.3± .9
-20 cm	2.0±0			4.0± .6	6.3± .7
-50 cm	0				

[1] ± = standard error.

Phosphorus Content of the Forest Floor

Depending on horizon, the mass of available phosphorus (P) was increased up to 50 times that in the unburned control and the concentration of available P to approximately 40 times that in the control (table 9). Maximum increases in P availability were found in the ashed green moss layer, 01, in the burned units; smaller increases in P concentration appeared in the partially charred 021 horizon (tenfold over the control) and 022 horizon (twofold over the control). Although charring was not readily evident in the 022 horizon, increases in P concentration, especially for the fuel loaded units, indicated that fine ash may have penetrated this layer either during the fire or through physical disturbance at the time of sample collection.

For the total forest floor a maximum increase in available P of approximately sevenfold occurred for the fuel loaded units and a fourfold increase for the nonloaded units.

The importance of increased available P to plant growth and soil microbial activity has yet to be established. General observation at sites of previous fires indicated rapid sprouting and growth of willow and aspen and marked improvement in productivity of blueberry (*Vaccinium uliginosum*). Reduced competition from other plants for moisture, light, and nutrients may be important. Elevated soil temperature resulting from darkened surfaces, as well as increased nutrient availability, may also stimulate growth of plant species after fire.

Postburn Vegetation

The 1-m^2 vegetation quadrats were inventoried immediately after the fire and at the end of the growing season, and the presence or absence of green needles and the percent of needles consumed by the fire were recorded for trees along the transects.

Table 9--Available phosphorus in forest floor of burned units and unburned control, Washington Creek experimental fire site[1/]

Available phosphorus and unit	Horizon of forest floor			
	01	021	022	Total
	Milligrams per square meter			
Mass of phosphorus:				
Control	5.1± 1.3	19.1± 4.9	52.2±19.9	76.3
1L	205.1±39.0	101.9± 9.5	203.3±53.9	510.3
2	201.8±58.0	46.4	77.7±31.3	325.9
3	180.1±31.9	91.1±13.8	66.7±23.6	337.9
4L	257.1±31.9	83.5±10.0	175.4±51.5	516.0
	Parts per million			
Concentration of phosphorus:				
Control	7.7± .4	11.3±		
1L	279.5±59.2	109.6±		
2	115.2±39.1	37.6		
3	227.1±41.8	70.5±1		
4L	308.8±33.7	71.2±1		

1/ ± = standard error.

Trees

Determining the percentage of trees immediately killed by the fire was impossible because some trees that appeared alive after the fire may not survive. To obtain some idea of the relative damage to the trees and saplings, we recorded the percentage of needles consumed by the fire soon after the fire and before the needles started to fall:

1. 76 to 100 percent
2. 51 to 75 percent
3. 26 to 50 percent
4. 0 to 25 percent; many needles green.

Table 10 shows a general relationship between the intensity of fire evaluated by other means and the percentage of needles consumed. Thus, units 2 and 4L, which had the hottest observed crown fires, had the highest percentage of needles consumed. All trees and saplings on unit 4L had 25 percent or more of the needles consumed. Only 9 percent of the trees in unit 3, which was subjected to a slow-moving fire that seldom crowned, had 75 to 100 percent of the needles consumed.

In general, more needles were consumed on the saplings than on the taller trees, which indicated that the hottest part of the fire was below the higher levels of the tree crowns.

The few birch trees within the stands appeared to be killed by the fire. Also, all alder and willow shrubs within the vegetation plots appeared to have been killed back to the soil surface.

Figures 8 through 15 are pairs of photographs of the same transects and vegetation plots before and after the fires. Figures 8 and 9, transect 1 in unit 2, show the large amount of material consumed by the fire. Figures 10 and 11 are of vegetation plot 31 within unit 2, burned on July 22. The post-fire photograph shows that the moss layer was killed by the fire, but little of the underlying organic layer was consumed.

Figures 12 and 13 are of transect 2 in unit 4L. This unit had the most intense fire. Figure 13 shows that most of the needles have been burned. Figures 14 and 15, of vegetation plot 63 from within the same unit, 4L, show that much of the organic material has been consumed by the fire.

Table 10--Consumption of needles of black spruce trees and saplings by fire, Washington Creek experimental fire site

Needles consumed	Unit 1L	Unit 2	Unit 3	Unit 4L
Percent		Percentage of trees[1]		
76-100	33	47	9	39
51-75	32	16	38	55
26-50	28	22	44	6
0-25	7	14	9	0
		Percentage of saplings[1]		
76-100	76	62	43	78
51-75	16	15	38	20
26-50	8	8	17	2
0-25	0	14	2	0

[1]Based on total number of trees and saplings in two 4-m by 32-m transects in each unit.

Figure 8.--Unit 2, transect 1, 1 year before the fire. Note the alder in left foreground, the dense branches of the spruce that reach nearly to the ground, and the ground cover of mosses and low shrubs.

Figure 9.--Unit 2, transect 1, on July 23, 1 day after the fire. Note that a large amount of needles and low shrubs have been consumed by the fire. Smoke from one small smoldering fire can be seen.

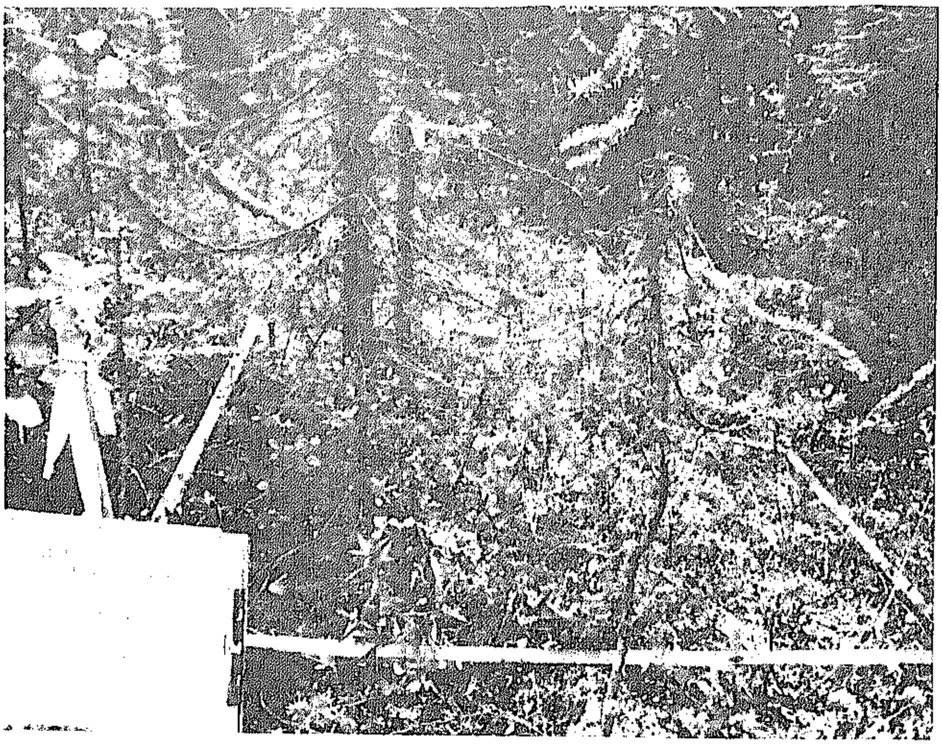


Figure 10.--Unit 2, vegetation plot 31, 1 year before the fire.

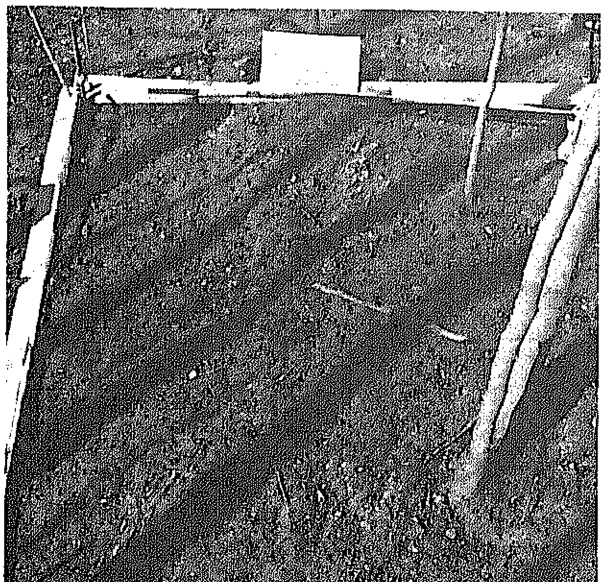


Figure 11.--Unit 2, vegetation plot 31 taken from the side opposite that shown in figure 10). Ground vegetation and low branches on the spruce have been almost totally consumed by the fire.

Revegetation

All the vegetation plots were inventoried immediately after the fire and in September, at the end of the growing season. In the units burned in late August, no vegetation had developed. All units indicated 100-percent destruction of above-ground vegetation except unit 1L, where one plot showed some unburned moss.

In unit 2, burned on July 22, there was some regrowth by the end of the summer. Shoots of both *Calamagrostis canadensis* and *Salix scouleriana*, having developed from underground parts not killed by the fire, were scattered throughout the stand. The shoots of *S. scouleriana* had reached a height of 30 cm. Approximately 70 percent of these shoots had been browsed by hares (*Lepus americanus*) by the end of September.

Figure 12.--Unit 4L, transect 2. Note abundance of branches and other fuels 0-2 m above the ground. The photograph was taken in June 1975, before additional black spruce were placed on the unit.

Figure 13.--Unit 4L, transect 2, 1 day after the fire. Most of the needles have been consumed by the fire. The boles of the spruce added to the unit can be seen on the ground.

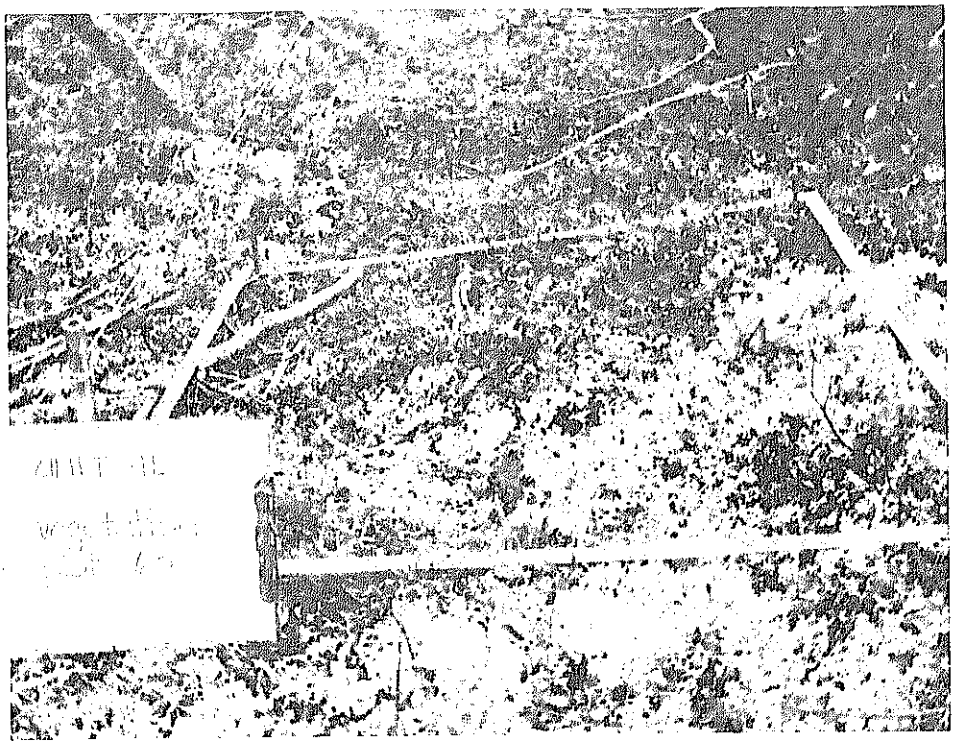


Figure 14.--Unit 4L, vegetation plot 63, 1 year before the fire. Note the abundance of fruticose lichens. The photograph was taken before additional black spruce were placed on the unit.

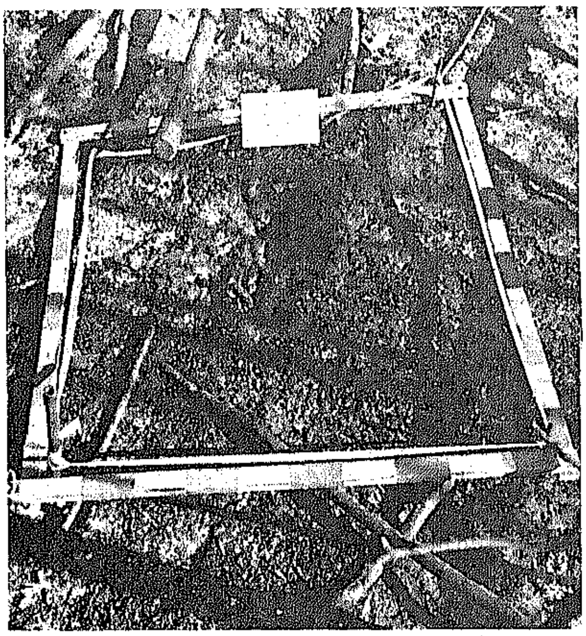


Figure 15.--Unit 4L, vegetation plot 63, 1 day after the fire. Note the heavy charring of the moss and lichen layer. Remains of the added black spruce can be seen in and around the unit.

Seed Fall

Black spruce has semiserotinous cones that open to release seed after fire. Seed traps were placed in each stand immediately after the fire, and the seed were collected weekly until the first snow. The results are shown in table 11. For the control area for the seed fall, we have used data from a nearby unburned study site in Washington Creek.

Seed fall began immediately after the August 26 fire, but not in quantities greatly exceeding the quantity from the control. During September, about twice as many seeds fell in units 2 and 3 as in the control. In unit 4L, where temperatures exceeded 454°C at 2.75 m, seed fall was much less. The fire may have been hot enough to actually consume many of the cones.

Fuel

The information obtained from the fuel measurements is shown in table 12. Before units 1L and 4L were loaded, quantities of downed fuels varied from 7.5 to 12.7 metric tons per hectare. Afterward the loaded units had 16.6 and 24.1 tons per hectare of downed fuels.

After the fires, three units showed no significant lowering of total fuel amounts. In fact, unit 3 showed an increase because of downed trees as result of the fire. Unit 4L, the most heavily burned, did show a reduction of more than half the downed dead fuels. All the units showed a decrease in the amount of the finest fuels--twigs below 0.64-cm diameter. Quantities of material considered to be rotted before the fire were recorded as zero in all the units.

Table 11--Black spruce seed dispersal at the Washington Creek experimental fire site compared with dispersal of seed in a nearby unburned stand1/

Date	Unburned control	Unit 1L	Unit 23/	Unit 32/	Unit 4L2/
		Seeds per square meter			
July:					
28	12.2±1.94		1.2±0.80		
August:					
4	14.2±4.62		20.0±4.42		
11	5.2± .96		14.8±4.48		
18	13.8±1.46		11.6±2.48		
24	4.8±1.40		6.0±1.26		
September:					
1	4.6±1.44	4/	14.0±3.50	5/	5/
7	5.4±1.14	4/	12.0±2.74	12.4±6.14	0.8±0.80
15	5.4±1.10	5/	16.4±2.30	14.8±8.42	1.6± .74
22	5.0±1.70	8.8± 3.24	8.7±4.14	11.6±6.30	.8± .48
October:					
6	4.6± .94	15.2±8.27	6.0±3.07	2.4±1.46	2.0±1.08

1/± = standard error.

2/Burned August 26.

3/Burned July 22.

4/No seed trap.

5/Trap installed.

Table 12--Downed fuels before and after 1976 experimental fires, Washington Creek experimental fire site

Fuel size class	Unit 1L		Unit 2		Unit 3		Unit 4L		Unburned control
	Before	After	Before	After	Before	After	Before	After	
Centimeters	Metric tons per hectare								
0-0.64	1.40	0.91	0.58	0.34	0.81	0.15	2.45	0.16	0.70
0.64-2.5	3.23	3.82	1.10	2.16	3.46	4.87	4.86	2.28	3.36
2.5-7.6	9.52	7.83	2.37	2.03	7.15	6.82	9.21	7.85	5.42
7.6+	1.90	3.45	1.25	1.63	.60	1.19	5.01	4.62	--
Rotted 7.6+	.54	--	2.21	--	.68	--	2.57	--	.75
Total	1/ 16.6	16.0	7.51	6.2	12.7	14.7	1/ 24.1	14.9	10.2
Total before loading	8.6						9.9		

1/ Total fuel after loading.

SUMMARY AND CONCLUSIONS

The conditions set up for these experimental fires were:

Fuel stick, moisture content	5 to 20 percent
Relative humidity	20 to 45 percent
Speed and direction of wind	0-4.5 m/s (0-10 mi/h), from S.W. to S.E.
Air temperature	10°- 27°C (50°-80°F)

Despite these rather generalized conditions, there were surprisingly few periods during the summer of 1976 when these conditions were met. Throughout most of the summer, fuels were too moist for a successful fire. Two dates on which burning limits were met were July 22 and August 26. One small experimental unit was burned in July, and three units were burned in August.

Although aboveground conditions were almost identical on the 2 burning days, depth of burning differed appreciably. This difference may mostly be attributed to moisture conditions of the forest floor at the time of burning. Because of periods of rainfall just before burning, forest floor moisture content was rather high on July 22--about 60 percent by volume at the cm depth. In contrast, it was only about 30 percent at 15 cm on August 26.

With one exception, the fires moved quickly across the units and completely covered the approximately 0.1-ha units in 6 to 9 minutes. On three out of four units, the fire quickly entered the crowns, although on only one (4L) did it crown in virtually all the trees on the unit. The exceptional unit was the last to be ignited on August 26. The fire on this unit was a slow-moving ground fire that took 30 minutes to traverse the unit.

After the fires, the burned units presented an appearance similar to that encountered in a wildfire area. Aboveground vegetation was almost completely killed, and the forest floor reflected a mosaic of different fire intensities. The average reduction in thickness of the forest floor ranged from 24 percent on unit 2 (burned July 22) to 62 percent on 4L. This striking difference was attributed to the higher content of water in forest floor materials on the July burning date. Likewise, proportions of areas within forest floor fire severity classes also reflected this difference in forest floor moisture content. For example, although the unit burned in July had only 2 percent of its area classed as heavily burned, the three units burned in August had about 34 to 58 percent of their total area in the heavily burned class.

Soil temperatures measured soon after the fires indicated that the heat generated by the fires had little long-lasting effect on soil temperatures. On the other hand, fire had a dramatic effect on the chemistry of the forest floor. Analysis of samples taken soon after the fires disclosed an increase of up to 50 times the amounts of available phosphorus in the burned area as in the unburned control. Maximum increases in P availability were in the upper portion of the forest floor--in the ashed green moss layer and the two units loaded with fuel.

Since these fires were only the first of a projected series of experimental fires, the main conclusions that will be helpful in designing future work are:

1. With the right fuel and climatic conditions, fire on small units in spruce can be made to simulate at least moderately severe wildfire conditions. When this study was initiated, we were uncertain whether fires would be sufficiently intense on such small units (only about 0.1 ha). For this reason two of the four units were loaded with fuel. It is now apparent that such loading was unnecessary, for the unloaded units burned with about the same intensity as the loaded units.

2. Future work with experimental fires in black spruce should, at the very least, include monitoring of forest floor moisture, as forest floor materials are an extremely important fuel in controlling fire effects in this type. Conditions other than forest floor moisture were almost identical at the time of the two periods of burning (July and August 1976); yet postfire characteristics on the unit burned in July were far different from those on units burned in August. Most of the differences could be explained by the high forest floor moisture content in July.

3. More efficient and accurate means of measuring fire intensity when the fire is underway are needed. In this study, we used temperature sensitive pellets and heat paints with indifferent success. More information is needed on such parameters as rate of spread, flame length, and weather variables to calculate fireline intensity.

4. A five-class forest floor fire severity class system works well for categorizing forest floor conditions after fire in black spruce--unburned, scorched, lightly burned, moderately burned, and heavily burned. We suggest that future soil sampling after fire be stratified on this basis. We have a long way to go to fully understand the considerable effects of fire on soil properties in the taiga.

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